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Inheritance of Active and Passive Immunity in Beef Calves

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Introduction

Disease is caused by successful invasion of pathogenic organisms (e.g., viruses, bacteria, parasites). The immune system is responsible for the protection of an individual against these invasions. This system is complex, with interconnective parts composed of many stimulators, inhibitors, effectors, and consequences. Immunity that is dependent upon antibodies or immunoglobulins can be either active or passive in origin. In active immunity, the body produces protecting antibodies in response to a naturally occurring infection or to vaccination against a pathogenic organism. Vaccination will prime the animal's immune system for a faster and more effective response to later infections. In passive immunity, temporary protection against infection results because of the transfer of immune products from a resistant to a susceptible individual. Passive immunity occurs between mother and young via transfer of immunoglobulins across the placenta to the developing fetus and/or by ingestion of immunoglobulin-containing colostrum. In ruminants, placental transfer of maternal antibodies does not occur due to the complexity of the placenta. The animal is born with a negligible level of immunoglobulins unless fetal infection has occurred. However, this is compensated for by absorption of large protein molecules, including immunoglobulins, from colostrum across the intestinal wall of the neonate. The absorptive mechanism is short-lived, lasting only 24 to 36 hr after birth, and absorption capacity decreases over time. Catabolism of these proteins eventually occurs in the body. Therefore, we believe maternal immunoglobulins are gone by 3 to 4 mo of age. As level of maternal antibodies declines, the animal's own immune system takes over the role of protection. Responses to natural infection and vaccination begin. Thus, both types of immunity are necessary for the well-being of the ruminant animal.

One approach to reducing losses due to disease is to increase genetic disease resistance. Improvement of genetic resistance requires identification of genetically superior animals and dissemination of their genes by preferential mating. However, before a clear definition of immune superiority is possible, factors that affect immune traits must be defined.

The first part of this study investigated the ability of calves to acquire and absorb colostral antibodies. The second part of this study investigated the animals' active immunity, specifically the vaccination response to infectious bovine rhinotracheitis virus (IBRV). Factors affecting these immune traits were examined, and heritabilities of these traits were estimated.

Procedure

Two beef cattle populations were included in the study. The first group was 367 Selection Experiment Herefords, including three selection lines and an unselected control line (CNL). The selection lines sampled were a weaning weight line (WWL), a yearling weight line (YWL), and a line selected for an index of yearling weight and muscling score (IXL). The second population was the Germ Plasm Utilization (GPU) Project. Straightbred Angus (79), Herefords (40), and Red Polls (46) were sampled. Three sets of blood samples were collected from each animal. The first set was taken from calves between 24 and 48 hr of age. Level of IgG_1, a specific class of immunoglobulin, was quantified in these samples in a single radial immunodiffusion (SRID) assay. The second set was taken from these same animals at time of vaccination for IBRV, and the third set was taken 60 days postvaccination. The second and third set of samples were quantified for antibody titers specific to IBRV by a kinetics-ELISA assay and are referred to as prevaccination and postvaccination titers, respectively.

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[2]The full report of this work was published in J. Anim. Sci. 64:385-393, 1987.

Table 1—Least-squares means for lines of the Selection Experiment Hereford population and breeds of the Germ Plasm Utilization population

Group	No.	IgG_1 level (mg/ml) at 24 to 48 hr	Prevaccination IBRV titer	Postvaccination IBRV titer
SEH[a] overall	367	26.0	4.8	13.8
Line[b]				
WWL	86	25.7[de]	4.5[de]	12.4[d]
YWL	88	22.4[d]	4.7[de]	13.9[de]
IXL	69	26.8[de]	4.4[d]	15.1[e]
CNL	124	28.9[e]	5.4[e]	13.7[de]
GPU[c] overall	165	33.6	4.6	8.8
Breed				
Angus	79	38.9[d]	4.3	8.9
Hereford	40	28.4[e]	5.2	8.9
Red Poll	46	33.4[e]	4.4	8.6

[a]Selection Experiment Hereford population.
[b]Line abbreviations are: weaning weight (WWL), yearling weight (YWL), index of yearling weight and muscling score (IXL), and randomly selected control line (CNL).
[c]Germ Plasm Utilization population.
[de]Means within the same trait and group with no superscript in common differ (probability < .05).

Table 2—Least-squares means for sex and age of dam effects in Selection Experiment Hereford calves

Effect	No.	IgG_1 level (mg/ml) at 24 to 48 hr	Prevaccination IBRV titer	Postvaccination IBRV titer
Sex				
Male	190	25.3	4.8	13.9
Female	177	26.6	4.7	13.7
Age of dam				
2 yr	97	20.3[a]	4.3[a]	17.1[a]
3 yr	92	26.6[b]	4.6[a]	14.4[b]
4-9 yr	178	31.0[c]	5.4[b]	9.9[c]

[abc]Means within the same trait and effect with no superscript in common differ (probability < .05).

Table 3—Least-squares means for sex and age of dam effects in Germ Plasm Utilization calves

Effect	No.	IgG_1 level (mg/ml) at 24 to 48 hr	Prevaccination IBRV titer	Postvaccination IBRV titer
Sex				
Male	89	33.3	4.5	8.3
Female	76	33.8	4.8	9.3
Age of dam				
3 yr	56	33.4	4.0	9.9[a]
4-7 yr	109	35.2	5.0	8.0[b]

[ab]Means within the same trait and effect with no superscript in common differ (probability < .05).

Table 4—Heritability estimates (h^2) for immune traits pooled across Selection Experiment Hereford and Germ Plasm Utilization populations

Trait	h^2
IgG_1 level (mg/ml) at 24 to 48 hr	.09
Prevaccination IBRV titer	.21
Postvaccination IBRV titer	-.06

Results

The traits measured in this study were IgG_1 level at 24 to 48 hr of age, prevaccination IBRV titer, and 60-day postvaccination IBRV titer. In Table 1, least-squares means of these traits are given for the Selection Experiment Hereford lines and for Angus, Hereford, and Red Poll calves of the GPU population. There were no consistent differences among lines or breeds for the traits measured. While the CNL line was highest in mean IgG_1 level and prevaccination titer, it was intermediate for postvaccination titer. Angus calves were higher in mean IgG_1 level than Hereford and Red Poll calves. At the time of 24 to 48 hr sampling, the Angus calves were observed to be more active than calves of the other two breeds. It may be that the time from birth to colostrum ingestion was less in Angus calves and so greater absorption of immunoglobulins occurred.

The effects of sex and age of dam on each trait were also examined. These effect means are given in Table 2 and Table 3 for the Selection Experiment Herefords and the GPU calves, respectively. No differences between sexes were found for any trait. However, interesting differences were found for the age of dam effect. The mean IgG_1 level was lower for calves of younger dams (2 and 3 yr of age) than for calves of older dams (4 yr and older). It may be that the younger dams (or their calves) experienced more pain at parturition, causing them to ignore or reject any teat-seeking advances (or attempts) by the newborn calf. Any delay in colostrum ingestion will cause a decreased protein absorption in the newborn's intestine, resulting in a decrease in serum immunoglobulin levels. Also, mammary gland development may not be complete in these younger dams, and the quantity of available immunoglobulins, including those specific to IBRV, may have been less. Calves of younger dams had a lower mean prevaccination titer than calves of older dams. It is possible that less maternal IBRV-specific antibodies were present in the prevaccination samples because less colostral antibodies were available to these calves of younger dams. A lower mean postvaccination titer was found for calves of older dams than for calves of younger dams. Any remaining IBRV-specific antibodies at time of vaccination would neutralize the vaccine before the calf's own immune system could respond. Therefore, calves with higher prevaccination titers (calves of older dams) would have lower responses measured 60 days later. Calves from younger dams would have lower levels of passive immunity, less maternal antibodies at time of vaccination, a greater response to the vaccination, and more antibodies measured 60 days later.

Heritability estimates for IgG_1 level at 24 to 48 hr of age, prevaccination IBRV titer, and 60-day postvaccination IBRV titer are given in Table 4. These estimates are pooled over the two populations, resulting in a single value for each trait. All estimates were low and nonsignificant, indicating that improvement of these traits through genetic selection would be difficult.

The effect of these immune traits on survival rate was examined for IgG_1 level at 24 to 48 hr of age. Fourteen Selection Experiment Hereford calves died during the calving season. The mean level for these calves (16.1 mg IgG_1/ml of serum) was significantly lower than the overall mean level for the Selection Experiment population (26.0 mg/ml). One Angus calf of the GPU population died during the calving season, and its IgG_1 level was 16.7 mg/ml. Seven additional Selection Experiment calves died between the end of calving and weaning. Their mean IgG_1 level was 23.7 mg/ml, and this was not significantly different from the overall mean. Thus, there was an increased risk of death associated with lower colostral immunoglobulin level, but this risk was evident only during the first 30 days of life.